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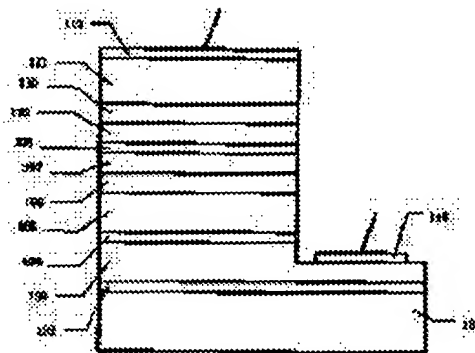
(72)Inventor : KIMURA AKITAKA
SUNAKAWA HARUO
NIDOU MASAOKI
SASAOKA CHIAKI

(54) NITRIDE COMPOUND SEMICONDUCTOR, CRYSTAL GROWTH METHOD THEREOF, AND GALLIUM NITRIDE LIGHT-EMITTING DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To enable a mirror plane to be formed by cleavage by a method, wherein an InGaN layer is formed on the specific surface of a sapphire substrate, and then gallium nitride or indium nitride or aluminum nitride or their mixed crystal is grown.

SOLUTION: An $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer 102 ($0.894 \leq x < 1$) formed on the surface of a sapphire substrate 101 which is a (0001) plane or a plane inclined to form an angle of 5° or less with a (0001) plane and gallium nitride or indium nitride or aluminum nitride or their mixed crystal formed thereon are provided. At this point, the $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer 102 is grown at a temperature of 400 or higher to 600°C or lower. The cleavage planes of high-temperature growth epitaxial layers 103 to 111 are parallel with that of the substrate 101. Therefore, the mirror plane of a resonator can be formed by cleaving the substrate 101, so that a complicated process such as a dry etching process can be dispensed with, and the mirror plane is superior in smoothness.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] Especially this invention relates to the crystal growth approach for forming the gallium nitride system compound semiconductor layer and this a substrate and whose cleavage plane correspond on silicon on sapphire about the crystal growth approach of gallium nitride, indium nitride, alumimium nitride, or those mixed crystal (following only nitride system compound semiconductor). Moreover, this invention relates to the gallium nitride system light emitting device which can form a mirror plane according to a cleavage especially about the light emitting device (following only gallium nitride system light emitting device) containing at least one layer of layers of a gallium nitride system compound semiconductor.

[0002]

[Description of the Prior Art] Compared with the conventional common compound semiconductors, such as indium phosphide and gallium arsenide, forbidden-band width-of-face energy of gallium nitride is large. Therefore, since a gallium nitride system compound semiconductor is green, the application to the light emitting device applied to ultraviolet, especially semiconductor laser (following only laser) is expected.

[0003] Conventionally the gallium nitride which is a typical gallium nitride system compound semiconductor Generally a field (11-20) (following Ath page) or (0001) a field (following C side) on the silicon on sapphire used as a front face by the organic metal chemical-vapor-deposition method After forming a gallium nitride low dental-curing length buffer layer at the temperature of about 500 degrees C Or after forming an alumimium nitride low dental-curing length buffer layer at the temperature of about 600 degrees C, the two-step grown method of forming a gallium nitride elevated-temperature growth epitaxial layer at the temperature of about 1000 degrees C was used. The low dental-curing length buffer layer of gallium nitride or alumimium nitride is formed in order to absorb the big lattice constant difference and coefficient-of-thermal-expansion difference which exist between gallium nitride and silicon on sapphire.

[0004] The [1000] shaft (following a-axis) lattice constant gallium nitride, alumimium nitride, indium nitride, and near the ordinary temperature of sapphire, respectively $a_{\text{GaN}}=3.1892\text{\AA}$, They are $a_{\text{AlN}}=3.11\text{\AA}$, $a_{\text{InN}}=3.54\text{\AA}$, and $a_{\text{sap}}=4.785\text{\AA}$. The coefficients of thermal expansion of a shaft orientations are $\Delta a_{\text{GaN}}/a_{\text{GaN}}=5.59\times 10^{-6}\text{K}^{-1}$, $\Delta a_{\text{AlN}}/a_{\text{AlN}}=4.49\times 10^{-6}\text{K}^{-1}$, $\Delta a_{\text{InN}}/a_{\text{InN}}=3.75\times 10^{-6}\text{K}^{-1}$, and $\Delta a_{\text{sap}}/a_{\text{sap}}=7.5\times 10^{-6}\text{K}^{-1}$, respectively. Moreover, the coefficients of thermal expansion of the direction of [0001] shafts (following c axis) gallium nitride, alumimium nitride, indium nitride, and near the ordinary temperature of sapphire are $\Delta c_{\text{GaN}}/c_{\text{GaN}}=3.17\times 10^{-6}\text{K}^{-1}$, $\Delta c_{\text{AlN}}/c_{\text{AlN}}=1.92\times 10^{-6}\text{K}^{-1}$, $\Delta c_{\text{InN}}/c_{\text{InN}}=2.85\times 10^{-6}\text{K}^{-1}$, and $\Delta c_{\text{sap}}/c_{\text{sap}}=8.5\times 10^{-6}\text{K}^{-1}$, respectively.

[0005] Drawing 5 is the outline sectional view of the typical gallium nitride system laser formed on C side silicon on sapphire by the crystal growth approach of the above conventional techniques (S. Nakamura et al., Jpn.J.Appl.Phys.35 (1996) L74).

[0006] In drawing 5 this gallium nitride system laser On the silicon on sapphire 101 used as a front face, C side n mold In_{0.1}Ga_{0.9} with a thickness of 0.1 micrometers by which a gallium nitride low dental-curing length buffer layer [of undoping with a thickness / 300Å / of with a growth temperature of 550 degrees C / 502], n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, and silicon were added The N layer 104, the n mold aluminum_{0.15}Ga_{0.85}N cladding layer 105 with a thickness of 0.4 micrometers by which silicon was added, n mold gallium nitride lightguide layer 106 with a thickness of 0.1 micrometers by which silicon was added, and

In_{0.2}Ga_{0.8} of undoping with a thickness of 25Å The multiplex quantum well structure barrier layer 107 of 26 periods which consist of N quantum well layers and In_{0.05}Ga_{0.95}N barrier layers of undoping with a thickness of 50Å, The p mold aluminum 0.2 with a thickness of 200Å with which magnesium was added Ga_{0.8} The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the In_{0.15}Ga_{0.85}N cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added of p molds, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 502, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0007] Drawing 6 is the outline sectional view of the typical gallium nitride system laser too formed on Ath page silicon on sapphire by the crystal growth approach of the above-mentioned conventional technique (S. Nakamura et al., Jpn.J.Appl.Phys.35(1996) L217). In drawing 6 this gallium nitride system laser On the silicon on sapphire 601 used as a front face, the Ath page n mold In_{0.1}Ga_{0.9} with a thickness of 0.1 micrometers by which a gallium nitride low dental-curing length buffer layer [of undoping with a thickness / 500Å / of with a growth temperature of 550 degrees C / 602], n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, and silicon were added The N layer 104, the n mold aluminum_{0.12}Ga_{0.88}N cladding layer 605 with a thickness of 0.4 micrometers by which silicon was added, n mold gallium nitride lightguide layer 106 with a thickness of 0.1 micrometers by which silicon was added, and In_{0.2}Ga_{0.8} of undoping with a thickness of 25Å The multiplex quantum well structure barrier layer 607 of 20 periods which consist of N quantum well layers and In_{0.05}Ga_{0.95}N barrier layers of undoping with a thickness of 50Å, The p mold aluminum 0.2 with a thickness of 200Å with which magnesium was added Ga_{0.8} The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the p mold aluminum_{0.15}Ga_{0.85}N cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 502, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0008] [Problem(s) to be Solved by the Invention] In the gallium nitride system laser formed on C side silicon on sapphire by the conventional technique as shown in drawing 5, the c axis of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. In this case, between silicon on sapphire and the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist. However, by the gallium nitride system laser of the conventional technique, since gallium nitride is very hard, it becomes inadequate absorbing [of the lattice constant difference by the low dental-curing length buffer layer and a coefficient-of-thermal-expansion difference], and this causes crystalline badness of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, and magnitude of a crack consistency.

[0009] Moreover, the field (following Mth page) used as the cleavage plane of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 formed on C side silicon on sapphire (1-100) makes the Mth page and the include angle of 30 degrees which are the cleavage plane of silicon on sapphire. This is the a-axis lattice constant aGaN of a gallium nitride low dental-curing length buffer layer. A-axis lattice constant asap of sapphire It is because it is close to asap/root3.

[0010] The physical relationship of the atom of the silicon on sapphire and the gallium nitride (or alumimium nitride) low dental-curing length buffer layer in this case is shown in drawing 4. A process with dry etching complicated since a resonator mirror plane cannot be formed according to the cleavage of a substrate which is represented by reactive ion etching for resonator niveau formation is required for the laser formed on conventional C side silicon on sapphire 101 as shown in drawing 4, and the smooth nature of a resonator mirror plane was not obtained. This is also the same as when an alumimium nitride low dental-curing length buffer layer is adopted instead of the gallium nitride low dental-curing length buffer layer 502.

[0011] Moreover, in the gallium nitride system laser formed on conventional Ath page silicon on sapphire as shown in

drawing 6, the c axis of the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. Also in this case, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist between silicon on sapphire and the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111. Since gallium nitride is very hard, it becomes inadequate absorbing [of the lattice constant difference by the low dental-curing length buffer layer and a coefficient-of-thermal-expansion difference]. It is the cause of the crystalline badness of the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111, or the magnitude of a crack consistency.

[0012] Moreover, the Mth page used as the cleavage plane of the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111 formed on Ath page silicon on sapphire makes the include angle of about 2.4 degrees but correctly almost in parallel with the field (following Rth page) which is a cleavage plane of a substrate (1-102). Therefore, although the resonator mirror plane of the laser formed on Ath page silicon on sapphire 601 by the crystal growth approach of this conventional technique could be formed according to the cleavage of a substrate, the difference in an include angle influenced and it was not able to acquire a smooth resonator mirror plane with sufficient repeatability. Moreover, this is also the same as when an alumimium nitride low dental-curing length buffer layer is adopted instead of the gallium nitride low dental-curing length buffer layer 602.

[0013] The object of this invention offers the crystal growth approach for forming the nitride system compound semiconductor layer and this silicon on sapphire and whose cleavage plane correspond, the crack consistency which enters well at the time of the semi-conductor stratification by crystal growth is small, and the crystallinity of a semi-conductor layer is realizing the gallium nitride system light emitting device which can form a mirror plane according to a cleavage.

[0014]

[Means for Solving the Problem] The crystal growth approach of the nitride system compound semiconductor of this invention is characterized by having the process which forms an $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field (0001) or (0001) a field is less than 5 degrees, and the process which grows gallium nitride, indium nitride, alumimium nitride, or those mixed crystal continuously. Moreover, it is characterized by growing up an $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) below 400 degrees C or more 600 degrees C.

[0015] The process which forms an $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field or (0001) a field is less than 5 degrees furthermore (0001) below 400 degrees C or more 600 degrees C, It is characterized by the process which forms an $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer ($0 \leq x < 1$) at 400-degree-C or more temperature of 700 degrees C or less, and forming gallium nitride, indium nitride, alumimium nitride, or those mixed crystal continuously.

[0016] Moreover, it is characterized by growing up a semi-conductor layer by the organic metal chemical-vapor-deposition method or hydride vapor growth.

[0017] The gallium nitride system light emitting device of this invention is characterized by having the $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) formed in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field (0001) or (0001) a field is less than 5 degrees, and the gallium nitride formed on said $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer, indium nitride, alumimium nitride or those mixed crystal. Moreover, said $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) is characterized by growing up below 400 degrees C or more 600 degrees C.

[0018] Furthermore, the $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer formed in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field (0001) or (0001) a field is less than 5 degrees below 400 degrees C or more 600 degrees C ($0.894 \leq x < 1$), The $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer formed on said $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer at 400-degree-C or more temperature of 700 degrees C or less ($0 \leq x < 1$), It is characterized by having the gallium nitride formed on said $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer, indium nitride, alumimium nitride, or those mixed crystal.

[0019]

[Embodiment of the Invention] The gestalt of operation of this invention is explained in detail with reference to a drawing based on an example.

[0020] <<example 1>> $\text{In}_{0.9}\text{Ga}_{0.1}\text{N}$ was adopted as a low dental-curing length buffer layer of gallium nitride system laser. Drawing 1 is the outline sectional view of this gallium nitride system laser. In drawing 1, gallium nitride system laser on the silicon on sapphire 101 which uses a field (0001) as a front face $\text{In}_{0.9}$ of undoping with a thickness [300Å] of with a growth temperature of 550 degrees C $\text{Ga}_{0.1}\text{N}$ low dental-curing length buffer layer 202, n mold

gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, the n mold $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ layer 104 with a thickness of 0.1 micrometers by which silicon was added, the n mold aluminum $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$ cladding layer 105 with a thickness of 0.4 micrometers by which silicon was added, The multiplex quantum well structure barrier layer 107 of 26 periods which consist of n mold gallium nitride lightguide layers 106 with a thickness of 0.1 micrometers, the $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ quantum well layers of undoping with a thickness of 25Å, and the $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ barrier layers of undoping with a thickness of 50Å by which silicon was added. The p mold aluminum $\text{Al}_{0.2}$ with a thickness of 200Å with which magnesium was added $\text{Ga}_{0.8}$ The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the p mold aluminum $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$ cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added. The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 202, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0021] The Mth page which is cleavage planes of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 by the gallium nitride system laser of this example is parallel to the Mth page which is cleavage planes of a substrate. This is the a-axis lattice constant a_{GaN} of $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$) which is a low dental-curing length buffer layer. It is the a-axis lattice constant a_{sap} of sapphire from $a_{\text{sap}}/\sqrt{3}$. It is because it is near. Silicon on sapphire and $\text{In}_x\text{Ga}_{1-x}\text{N}$ in this case The physical relationship of the atom of a low dental-curing length buffer layer is shown in drawing 3. Therefore, since the laser formed on C side silicon on sapphire 101 by the crystal growth approach of this conventional technique can form a resonator mirror plane according to the cleavage of a substrate, its complicated process of dry etching which is represented by reactive ion etching for resonator niveau formation is unnecessary, and dramatically excellent also in smooth nature.

[0022] Furthermore by the gallium nitride system laser of this example, the c axis of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. In this case, between silicon on sapphire and the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist. However, by the gallium nitride system laser of this example, $\text{In}_{0.9}\text{Ga}_{0.1}\text{N}$ is used as a low dental-curing length buffer layer, and since $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0 < x < 1$) is softer than gallium nitride, a low dental-curing length buffer layer tends to absorb the lattice constant difference and coefficient-of-thermal-expansion difference between a substrate and a gallium nitride system compound semiconductor layer. For this reason, compared with the gallium nitride system laser according [the gallium nitride system laser of this example] to the conventional technique, the crystallinity of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 and a crack consistency are improved.

[0023] Although the low dental-curing length of the $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$) layer was carried out to the silicon-on-sapphire side in consideration of crystallinity or a crack consistency in this example, if its attention is paid only to a cleavage, it is not necessary to be low dental-curing length.

[0024] The presentation of an $\text{In}_x\text{Ga}_{1-x}\text{N}$ buffer layer is described below about the antecedent basis specified as ($0.894 \leq x < 1$). Lattice constant a_{InN} of InN Lattice constant a_{GaN} of GaN By complementing between in a straight line, it is the lattice constant a_{InGa} of $\text{In}_x\text{Ga}_{1-x}\text{N}$. If it asks, they are $a_{\text{InGa}} = x \cdot a_{\text{InN}} + (1-x) \cdot a_{\text{GaN}}$. It becomes.

[0025] It is as follows when the grid mismatching epsilon between the substrates and epitaxial growth phases at the time of forming this InGaN on silicon on sapphire is searched for.

[0026] i) -- the case where M side of a substrate and M side of an epitaxial layer are in agreement -- $\epsilon = (a_{\text{InGa}} - a_{\text{sap}}) / a_{\text{sap}}$ -- $\epsilon = \epsilon_1$ -- ϵ_1 [when making the include angle whose M side of ii substrate and M side of an epitaxial layer to carry out are 30 degrees] $= (a_{\text{InGa}} - a_{\text{sap}} / \sqrt{3}) / (a_{\text{sap}} / \sqrt{3})$
 $= \epsilon_2$ It is $\epsilon_1 \leq \epsilon_2$ from i and ii to carry out. When the becoming conditions are searched for, it is $a_{\text{sap}} = 4.785 \text{ Å}$. $0.894 \leq x$ It becomes.

[0027] This specified the range of x of $\text{In}_x\text{Ga}_{1-x}\text{N}$ as $0.894 \leq x < 1$.

[0028] <<example 2>> $\text{In}_{0.9}\text{Ga}_{0.1}\text{N}$ (the 1st layer) and gallium nitride (the 2nd layer) were adopted as a low dental-curing length buffer layer of gallium nitride system laser. Drawing 2 is the outline sectional view of this gallium nitride system laser. In drawing 2, gallium nitride system laser on the silicon on sapphire 101 which uses a field (0001) as a

front face In_{0.9} of undoping with a thickness [300Å] of with a growth temperature of 550 degrees C The n mold In_{0.1} with a thickness of 0.1 micrometers with which the Ga_{0.1} N low dental-curing length buffer layer 202, the gallium nitride low dental-curing length buffer layer 302 of undoping with a thickness [300Å] of with a growth temperature of 550 degrees C, n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, and silicon were added In_{0.2} of undoping with a Ga_{0.9} N layer [104], an n mold aluminum_{0.15}Ga_{0.85}N cladding layer [105] of with a thickness of 0.4 micrometers by which silicon was added, an n mold gallium nitride lightguide layer [106] of with a thickness of 0.1 micrometers by which silicon was added, and a thickness of 25Å Ga_{0.8} The multiplex quantum well structure barrier layer 107 of 26 periods which consist of N quantum well layers and In_{0.05}Ga_{0.95}N barrier layers of undoping with a thickness of 50Å, The p mold aluminum 0.2 with a thickness of 200Å with which magnesium was added Ga_{0.8} The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the p mold aluminum_{0.15}Ga_{0.85}N cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 202, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0029] The Mth page which is cleavage planes of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 by the gallium nitride system laser of this example is parallel to the Mth page which is cleavage planes of a substrate. This is the a-axis lattice constant a_{GaN} of In_x Ga_{1-x} N ($0.894 \leq x < 1$) which is the 1st layer of a low dental-curing length buffer layer. It is the a-axis lattice constant a_{sp} of sapphire from a_{sp}/root3. It is because it is near. Silicon on sapphire and In_x Ga_{1-x} N in this case The physical relationship of the atom of a low dental-curing length buffer layer is shown in drawing 3 . Therefore, since the laser formed on C side silicon on sapphire 101 by the crystal growth approach of this conventional technique can form a resonator mirror plane according to the cleavage of a substrate, its complicated process of dry etching which is represented by reactive ion etching for resonator niveau formation is unnecessary, and dramatically excellent also in smooth nature.

[0030] Furthermore, by the gallium nitride system laser of this example, the c axis of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. In this case, between silicon on sapphire and the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist. However, by the gallium nitride system laser of this example, In_{0.9} Ga_{0.1} N is used as the 1st layer of a low dental-curing length buffer layer, and since In_x Ga_{1-x} N ($0 < x < 1$) is softer than gallium nitride, a low dental-curing length buffer layer tends to absorb the lattice constant difference and coefficient-of-thermal-expansion difference between a substrate and a gallium nitride system compound semiconductor layer. For this reason, compared with the gallium nitride system laser according [the gallium nitride system laser of this example] to the conventional technique, the crystallinity of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 and a crack consistency are improved.

[0031] Furthermore, by the gallium nitride system laser of this example, gallium nitride is used as the 2nd layer of a low dental-curing length buffer layer. In order for this to form n mold gallium nitride contact layer 103 which is the 1st layer of an elevated-temperature growth epitaxial layer, when temperature up of the substrate is carried out to about 1000 degrees C, the reevaporation of the indium in the In_{0.9} Ga_{0.1} N layer which is the 1st layer of a low dental-curing length buffer layer can be prevented. In addition, although gallium nitride was used as the 2nd layer of a low dental-curing length buffer layer, you may be an Al_xGa_{1-x} N ($0 \leq x < 1$) layer.

[0032] The crystal growth approach of the nitride system compound semiconductor of this invention is not necessarily effective in the layer system shown in the example mentioned above, and is effective in the crystal growth approach of the nitride system compound semiconductor of all layer systems.

[0033] Moreover, the gallium nitride system light emitting device of this invention is not necessarily effective in the laser structure shown in the example mentioned above, and is effective in the gallium nitride system laser of all structures. Furthermore, the gallium nitride system light emitting device of this invention is not necessarily effective in laser, and is effective also in light emitting diode. It is because it is advantageous that the cleavage plane of a substrate and an elevated-temperature growth epitaxial layer is in agreement also in light emitting diode in respect of the yield in the case of isolation etc. In addition, as shown in the example 2, it is not necessary to be C side strictly, and about

surface side bearing of the silicon on sapphire in this invention, to C side, if it is less than 5-degree dip, it will be uninfluent in the effectiveness of this invention.

[0034]

[Effect of the Invention] As explained above, using the silicon on sapphire which uses C side as a front face as a substrate, the crystal growth approach of the nitride system compound semiconductor of this invention is adopting $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$) as a buffer layer, and can offer the nitride system compound system semi-conductor with which the cleavage plane of a substrate and the cleavage plane of a growth phase become parallel. Moreover, by acting as the low dental-curing length of $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$), the crystallinity of an elevated-temperature growth epitaxial layer and a crack consistency are also improvable.

[0035] Are generated by furthermore having adopted $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0 < x < 1$) as a low dental-curing length buffer layer. The problem of the reevaporation of the indium in the $\text{In}_x\text{Ga}_{1-x}\text{N}$ low dental-curing length buffer layer at the time of carrying out temperature up of the substrate, in order to form an elevated-temperature growth epitaxial layer is solvable by forming an $\text{Al}_x\text{Ga}_{1-x}\text{N}$ ($0 \leq x < 1$) layer as the 2nd layer of a low dental-curing length buffer layer. Therefore, the above effectiveness is expectable also in the gallium nitride system light emitting device of this invention in which the semi-conductor layer was formed using the crystal growth approach of this invention.

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TECHNICAL FIELD

[Field of the Invention] Especially this invention relates to the crystal growth approach for forming the gallium nitride system compound semiconductor layer and this a substrate and whose cleavage plane correspond on silicon on sapphire about the crystal growth approach of gallium nitride, indium nitride, aluminum nitride, or those mixed crystal (following only nitride system compound semiconductor). Moreover, this invention relates to the gallium nitride system light emitting device which can form a mirror plane according to a cleavage especially about the light emitting device (following only gallium nitride system light emitting device) containing at least one layer of layers of a gallium nitride system compound semiconductor.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] Compared with the conventional common compound semiconductors, such as indium phosphide and gallium arsenide, forbidden-band width-of-face energy of gallium nitride is large. Therefore, since a gallium nitride system compound semiconductor is green, the application to the light emitting device applied to ultraviolet, especially semiconductor laser (following only laser) is expected.

[0003] Conventionally the gallium nitride which is a typical gallium nitride system compound semiconductor Generally a field (11-20) (following Ath page) or (0001) a field (following C side) on the silicon on sapphire used as a front face by the organic metal chemical-vapor-deposition method After forming a gallium nitride low dental-curing length buffer layer at the temperature of about 500 degrees C Or after forming an alumimium nitride low dental-curing length buffer layer at the temperature of about 600 degrees C, the two-step grown method of forming a gallium nitride elevated-temperature growth epitaxial layer at the temperature of about 1000 degrees C was used. The low dental-curing length buffer layer of gallium nitride or alumimium nitride is formed in order to absorb the big lattice constant difference and coefficient-of-thermal-expansion difference which exist between gallium nitride and silicon on sapphire.

[0004] The [1000] shaft (following a-axis) lattice constant gallium nitride, alumimium nitride, indium nitride, and near the ordinary temperature of sapphire, respectively $a_{\text{GaN}} = 3.1892\text{\AA}$, They are $a_{\text{AlN}} = 3.11\text{\AA}$, $a_{\text{InN}} = 3.54\text{\AA}$, and $a_{\text{sap}} = 4.785\text{\AA}$. The coefficients of thermal expansion of a shaft orientations are $\Delta a_{\text{GaN}}/a_{\text{GaN}} = 5.59 \times 10^{-6}\text{K}^{-1}$, $\Delta a_{\text{AlN}}/a_{\text{AlN}} = 4.49 \times 10^{-6}\text{K}^{-1}$, $\Delta a_{\text{InN}}/a_{\text{InN}} = 3.75 \times 10^{-6}\text{K}^{-1}$, and $\Delta a_{\text{sap}}/a_{\text{sap}} = 7.5 \times 10^{-6}\text{K}^{-1}$, respectively. Moreover, the coefficients of thermal expansion of the direction of [0001] shafts (following c axis) gallium nitride, alumimium nitride, indium nitride, and near the ordinary temperature of sapphire are $\Delta c_{\text{GaN}}/c_{\text{GaN}} = 3.17 \times 10^{-6}\text{K}^{-1}$, $\Delta c_{\text{AlN}}/c_{\text{AlN}} = 1.92 \times 10^{-6}\text{K}^{-1}$, $\Delta c_{\text{InN}}/c_{\text{InN}} = 2.85 \times 10^{-6}\text{K}^{-1}$, and $\Delta c_{\text{sap}}/c_{\text{sap}} = 8.5 \times 10^{-6}\text{K}^{-1}$, respectively.

[0005] Drawing 5 is the outline sectional view of the typical gallium nitride system laser formed on C side silicon on sapphire by the crystal growth approach of the above conventional techniques (S. Nakamura et al., Jpn.J.Appl.Phys.35 (1996) L74).

[0006] In drawing 5 this gallium nitride system laser On the silicon on sapphire 101 used as a front face, C side n mold $\text{In}_{0.1}\text{Ga}_{0.9}$ with a thickness of 0.1 micrometers by which a gallium nitride low dental-curing length buffer layer [of undoping with a thickness / 300Å / of with a growth temperature of 550 degrees C / 502], n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, and silicon were added The N layer 104, the n mold $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$ cladding layer 105 with a thickness of 0.4 micrometers by which silicon was added, n mold gallium nitride lightguide layer 106 with a thickness of 0.1 micrometers by which silicon was added, and $\text{In}_{0.2}\text{Ga}_{0.8}$ of undoping with a thickness of 25Å The multiplex quantum well structure barrier layer 107 of 26 periods which consist of N quantum well layers and $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ barrier layers of undoping with a thickness of 50Å, The p mold $\text{Al}_{0.2}$ with a thickness of 200Å with which magnesium was added $\text{Ga}_{0.8}$ The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the $\text{In}_{0.15}\text{Ga}_{0.85}\text{N}$ cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added of p molds, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 502, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0007] Drawing 6 is the outline sectional view of the typical gallium nitride system laser too formed on Ath page silicon on sapphire by the crystal growth approach of the above-mentioned conventional technique (S. Nakamura et al., Jpn.J.Appl.Phys.35(1996) L217). In drawing 6 this gallium nitride system laser On the silicon on sapphire 601 used as a front face, the Ath page n mold $\text{In}_{0.1}\text{Ga}_{0.9}$ with a thickness of 0.1 micrometers by which a gallium nitride low dental-curing length buffer layer [of undoping with a thickness / 500A / of with a growth temperature of 550 degrees C / 602], n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, and silicon were added The N layer 104, the n mold aluminum $0.12\text{Ga}_{0.88}\text{N}$ cladding layer 605 with a thickness of 0.4 micrometers by which silicon was added, n mold gallium nitride lightguide layer 106 with a thickness of 0.1 micrometers by which silicon was added, and $\text{In}_{0.2}\text{Ga}_{0.8}$ of undoping with a thickness of 25A The multiplex quantum well structure barrier layer 607 of 20 periods which consist of N quantum well layers and $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ barrier layers of undoping with a thickness of 50A, The p mold aluminum 0.2 with a thickness of 200A with which magnesium was added $\text{Ga}_{0.8}$ The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the p mold aluminum $0.15\text{Ga}_{0.85}\text{N}$ cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 502, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[Translation done.]

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EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, using the silicon on sapphire which uses C side as a front face as a substrate, the crystal growth approach of the nitride system compound semiconductor of this invention is adopting $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$) as a buffer layer, and can offer the nitride system compound system semi-conductor with which the cleavage plane of a substrate and the cleavage plane of a growth phase become parallel. Moreover, by acting as the low dental-curing length of $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$), the crystallinity of an elevated-temperature growth epitaxial layer and a crack consistency are also improvable.

[0035] Are generated by furthermore having adopted $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0 < x < 1$) as a low dental-curing length buffer layer. The problem of the reevaporation of the indium in the $\text{In}_x\text{Ga}_{1-x}\text{N}$ low dental-curing length buffer layer at the time of carrying out temperature up of the substrate, in order to form an elevated-temperature growth epitaxial layer is solvable by forming an $\text{Al}_x\text{Ga}_{1-x}\text{N}$ ($0 \leq x < 1$) layer as the 2nd layer of a low dental-curing length buffer layer. Therefore, the above effectiveness is expectable also in the gallium nitride system light emitting device of this invention in which the semi-conductor layer was formed using the crystal growth approach of this invention.

[Translation done.]

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 TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] In the gallium nitride system laser formed on C side silicon on sapphire by the conventional technique as shown in drawing 5, the c axis of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. In this case, between silicon on sapphire and the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist. However, by the gallium nitride system laser of the conventional technique, since gallium nitride is very hard, it becomes inadequate absorbing [of the lattice constant difference by the low dental-curing length buffer layer and a coefficient-of-thermal-expansion difference], and this causes crystalline badness of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, and magnitude of a crack consistency.

[0009] Moreover, the field (following Mth page) used as the cleavage plane of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 formed on C side silicon on sapphire (1-100) makes the Mth page and the include angle of 30 degrees which are the cleavage plane of silicon on sapphire. This is the a-axis lattice constant aGaN of a gallium nitride low dental-curing length buffer layer. A-axis lattice constant asap of sapphire. It is because it is close to $\text{asap}/\sqrt{3}$.

[0010] The physical relationship of the atom of the silicon on sapphire and the gallium nitride (or aluminium nitride) low dental-curing length buffer layer in this case is shown in drawing 4. A process with dry etching complicated since a resonator mirror plane cannot be formed according to the cleavage of a substrate which is represented by reactive ion etching for resonator niveau formation is required for the laser formed on conventional C side silicon on sapphire 101 as shown in drawing 4, and the smooth nature of a resonator mirror plane was not obtained. This is also the same as when an aluminium nitride low dental-curing length buffer layer is adopted instead of the gallium nitride low dental-curing length buffer layer 502.

[0011] Moreover, in the gallium nitride system laser formed on conventional Ath page silicon on sapphire as shown in drawing 6, the c axis of the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. Also in this case, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist between silicon on sapphire and the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111. Since gallium nitride is very hard, it becomes inadequate absorbing [of the lattice constant difference by the low dental-curing length buffer layer and a coefficient-of-thermal-expansion difference]. It is the cause of the crystalline badness of the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111, or the magnitude of a crack consistency.

[0012] Moreover, the Mth page used as the cleavage plane of the elevated-temperature growth epitaxial layers 102, 103, 104, 105, 106, 107, 108, 109, 110, and 111 formed on Ath page silicon on sapphire makes the include angle of about 2.4 degrees but correctly almost in parallel with the field (following Rth page) which is a cleavage plane of a substrate (1-102). Therefore, although the resonator mirror plane of the laser formed on Ath page silicon on sapphire 601 by the crystal growth approach of this conventional technique could be formed according to the cleavage of a substrate, the difference in an include angle influenced and it was not able to acquire a smooth resonator mirror plane with sufficient repeatability. Moreover, this is also the same as when an aluminium nitride low dental-curing length buffer layer is adopted instead of the gallium nitride low dental-curing length buffer layer 602.

[0013] The object of this invention offers the crystal growth approach for forming the nitride system compound semiconductor layer and this silicon on sapphire and whose cleavage plane correspond, the crack consistency which

enters well at the time of the semi-conductor stratification by crystal growth is small, and the crystallinity of a semi-conductor layer is realizing the gallium nitride system light emitting device which can form a mirror plane according to a cleavage.

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MEANS

[Means for Solving the Problem] The crystal growth approach of the nitride system compound semiconductor of this invention is characterized by having the process which forms an $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field (0001) or (0001) a field is less than 5 degrees, and the process which grows gallium nitride, indium nitride, aluminum nitride, or those mixed crystal continuously. Moreover, it is characterized by growing up an $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) below 400 degrees C or more 600 degrees C.

[0015] The process which forms an $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field or (0001) a field is less than 5 degrees furthermore (0001) below 400 degrees C or more 600 degrees C, It is characterized by the process which forms an $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer ($0 \leq x < 1$) at 400-degree-C or more temperature of 700 degrees C or less, and forming gallium nitride, indium nitride, aluminum nitride, or those mixed crystal continuously.

[0016] Moreover, it is characterized by growing up a semi-conductor layer by the organic metal chemical-vapor-deposition method or hydride vapor growth.

[0017] The gallium nitride system light emitting device of this invention is characterized by having the $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) formed in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field (0001) or (0001) a field is less than 5 degrees, and the gallium nitride formed on said $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer, indium nitride, aluminum nitride or those mixed crystal. Moreover, said $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer ($0.894 \leq x < 1$) is characterized by growing up below 400 degrees C or more 600 degrees C.

[0018] Furthermore, the $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer formed in the front face on the silicon on sapphire which uses as a front face the field whose tilt angle from a field (0001) or (0001) a field is less than 5 degrees below 400 degrees C or more 600 degrees C ($0.894 \leq x < 1$), The $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer formed on said $\text{In}_x\text{Ga}_{1-x}\text{N}$ layer at 400-degree-C or more temperature of 700 degrees C or less ($0 \leq x < 1$), It is characterized by having the gallium nitride formed on said $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer, indium nitride, aluminum nitride, or those mixed crystal.

[0019]

[Embodiment of the Invention] The gestalt of operation of this invention is explained in detail with reference to a drawing based on an example.

[0020] <<example 1>> $\text{In}_{0.9}\text{Ga}_{0.1}\text{N}$ was adopted as a low dental-curing length buffer layer of gallium nitride system laser. Drawing 1 is the outline sectional view of this gallium nitride system laser. In drawing 1, gallium nitride system laser on the silicon on sapphire 101 which uses a field (0001) as a front face $\text{In}_{0.9}$ of undoping with a thickness [300A] of with a growth temperature of 550 degrees C $\text{Ga}_{0.1}\text{N}$ low dental-curing length buffer layer 202, n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, the n mold $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ layer 104 with a thickness of 0.1 micrometers by which silicon was added, the n mold aluminum $0.15\text{Ga}_{0.85}\text{N}$ cladding layer 105 with a thickness of 0.4 micrometers by which silicon was added, The multiplex quantum well structure barrier layer 107 of 26 periods which consist of n mold gallium nitride lightguide layers 106 with a thickness of 0.1 micrometers, the $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ quantum well layers of undoping with a thickness of 25A, and the $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ barrier layers of undoping with a thickness of 50A by which silicon was added, The p mold aluminum 0.2 with a thickness of 200A with which magnesium was added $\text{Ga}_{0.8}$ The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the p mold aluminum $0.15\text{Ga}_{0.85}\text{N}$ cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added, p

mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 202, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0021] The Mth page which is cleavage planes of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 by the gallium nitride system laser of this example is parallel to the Mth page which is cleavage planes of a substrate. This is the a-axis lattice constant aGaN of $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$) which is a low dental-curing length buffer layer. It is the a-axis lattice constant asap of sapphire from $\text{asap}/\sqrt{3}$. It is because it is near. Silicon on sapphire and $\text{In}_x\text{Ga}_{1-x}\text{N}$ in this case The physical relationship of the atom of a low dental-curing length buffer layer is shown in drawing 3. Therefore, since the laser formed on C side silicon on sapphire 101 by the crystal growth approach of this conventional technique can form a resonator mirror plane according to the cleavage of a substrate, its complicated process of dry etching which is represented by reactive ion etching for resonator niveau formation is unnecessary, and dramatically excellent also in smooth nature.

[0022] Furthermore by the gallium nitride system laser of this example, the c axis of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. In this case, between silicon on sapphire and the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist. However, by the gallium nitride system laser of this example, $\text{In}_{0.9}\text{Ga}_{0.1}\text{N}$ is used as a low dental-curing length buffer layer, and since $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0 < x < 1$) is softer than gallium nitride, a low dental-curing length buffer layer tends to absorb the lattice constant difference and coefficient-of-thermal-expansion difference between a substrate and a gallium nitride system compound semiconductor layer. For this reason, compared with the gallium nitride system laser according [the gallium nitride system laser of this example] to the conventional technique, the crystallinity of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 and a crack consistency are improved.

[0023] Although the low dental-curing length of the $\text{In}_x\text{Ga}_{1-x}\text{N}$ ($0.894 \leq x < 1$) layer was carried out to the silicon-on-sapphire side in consideration of crystallinity or a crack consistency in this example, if its attention is paid only to a cleavage, it is not necessary to be low dental-curing length.

[0024] The presentation of an $\text{In}_x\text{Ga}_{1-x}\text{N}$ buffer layer is described below about the antecedent basis specified as ($0.894 \leq x < 1$). Lattice constant aInN of InN Lattice constant aGaN of GaN By complementing between in a straight line, it is the lattice constant aInGaN of $\text{In}_x\text{Ga}_{1-x}\text{N}$. If it asks, they are $a\text{InGaN} = x \cdot a\text{InN} + (1-x) \cdot a\text{GaN}$. It becomes.

[0025] It is as follows when the grid mismatching epsilon between the substrates and epitaxial growth phases at the time of forming this InGaN on silicon on sapphire is searched for.

[0026] i) -- the case where M side of a substrate and M side of an epitaxial layer are in agreement -- $\epsilon = (a\text{asap} - a\text{InGaN}) / a\text{asap} = \epsilon_1$ ** -- $\epsilon = (a\text{InGaN} - a\text{asap}/\sqrt{3}) / (a\text{asap}/\sqrt{3})$ when making the include angle whose M side of ii substrate and M side of an epitaxial layer to carry out are 30 degrees]

= ϵ_2 It is $\epsilon_1 \leq \epsilon_2$ from i and ii to carry out. When the becoming conditions are searched for, it is $a\text{asap} = 4.785 \text{ \AA}$. $0.894 \leq x$ It becomes.

[0027] This specified the range of x of $\text{In}_x\text{Ga}_{1-x}\text{N}$ as $0.894 \leq x < 1$.

[0028] <<example 2>> $\text{In}_{0.9}\text{Ga}_{0.1}\text{N}$ (the 1st layer) and gallium nitride (the 2nd layer) were adopted as a low dental-curing length buffer layer of gallium nitride system laser. Drawing 2 is the outline sectional view of this gallium nitride system laser. In drawing 2, gallium nitride system laser on the silicon on sapphire 101 which uses a field (0001) as a front face $\text{In}_{0.9}$ of undoping with a thickness [300Å] of with a growth temperature of 550 degrees C The n mold $\text{In}_{0.1}$ with a thickness of 0.1 micrometers with which the $\text{Ga}_{0.1}\text{N}$ low dental-curing length buffer layer 202, the gallium nitride low dental-curing length buffer layer 302 of undoping with a thickness [300Å] of with a growth temperature of 550 degrees C, n mold gallium nitride contact layer 103 with a thickness of 3 micrometers by which silicon was added, and silicon were added $\text{In}_{0.2}$ of undoping with a $\text{Ga}_{0.9}\text{N}$ layer [104], an n mold aluminum $_{0.15}\text{Ga}_{0.85}\text{N}$ cladding layer [105] of with a thickness of 0.4 micrometers by which silicon was added, an n mold gallium nitride lightguide layer [106] of with a thickness of 0.1 micrometers by which silicon was added, and a thickness of 25Å $\text{Ga}_{0.8}$ The multiplex quantum well structure barrier layer 107 of 26 periods which consist of N quantum well layers and $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ barrier layers of undoping with a thickness of 50Å, The p mold aluminum 0.2 with a thickness of 200Å

with which magnesium was added Ga_{0.8} The N layer 108, p mold gallium nitride lightguide layer 109 with a thickness of 0.1 micrometers by which magnesium was added, the p mold aluminum_{0.15}Ga_{0.85}N cladding layer 110 with a thickness of 0.4 micrometers by which magnesium was added, p mold gallium nitride contact layer 111 with a thickness of 0.5 micrometers by which magnesium was added, The n electrode 113 which consists of the p electrode 112, titanium (the 1st layer), and aluminum (the 2nd layer) which consist of nickel (the 1st layer) and gold (the 2nd layer) is formed. Formation of the semiconducting crystal layers 202, 103, 104, 105, 106, 107, 108, 109, 110, and 111 was performed by the organic metal chemical-vapor-deposition method.

[0029] The Mth page which is cleavage planes of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 by the gallium nitride system laser of this example is parallel to the Mth page which is cleavage planes of a substrate. This is the a-axis lattice constant a_{GaN} of In_x Ga_{1-x} N ($0.894 \leq x < 1$) which is the 1st layer of a low dental-curing length buffer layer. It is the a-axis lattice constant a_{sap} of sapphire from a_{sap}/root3. It is because it is near. Silicon on sapphire and In_x Ga_{1-x} N in this case The physical relationship of the atom of a low dental-curing length buffer layer is shown in drawing 3. Therefore, since the laser formed on C side silicon on sapphire 101 by the crystal growth approach of this conventional technique can form a resonator mirror plane according to the cleavage of a substrate, its complicated process of dry etching which is represented by reactive ion etching for resonator niveau formation is unnecessary, and dramatically excellent also in smooth nature.

[0030] Furthermore, by the gallium nitride system laser of this example, the c axis of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 becomes vertical to a substrate front face. In this case, between silicon on sapphire and the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111, a big lattice constant difference and a coefficient-of-thermal-expansion difference exist. However, by the gallium nitride system laser of this example, In_{0.9} Ga_{0.1} N is used as the 1st layer of a low dental-curing length buffer layer, and since In_x Ga_{1-x} N ($0 < x < 1$) is softer than gallium nitride, a low dental-curing length buffer layer tends to absorb the lattice constant difference and coefficient-of-thermal-expansion difference between a substrate and a gallium nitride system compound semiconductor layer. For this reason, compared with the gallium nitride system laser according [the gallium nitride system laser of this example] to the conventional technique, the crystallinity of the elevated-temperature growth epitaxial layers 103, 104, 105, 106, 107, 108, 109, 110, and 111 and a crack consistency are improved.

[0031] Furthermore, by the gallium nitride system laser of this example, gallium nitride is used as the 2nd layer of a low dental-curing length buffer layer. In order for this to form n mold gallium nitride contact layer 103 which is the 1st layer of an elevated-temperature growth epitaxial layer, when temperature up of the substrate is carried out to about 1000 degrees C, the reevaporation of the indium in the In_{0.9} Ga_{0.1} N layer which is the 1st layer of a low dental-curing length buffer layer can be prevented. In addition, although gallium nitride was used as the 2nd layer of a low dental-curing length buffer layer, you may be an Al_xGa_{1-x} N ($0 \leq x < 1$) layer.

[0032] The crystal growth approach of the nitride system compound semiconductor of this invention is not necessarily effective in the layer system shown in the example mentioned above, and is effective in the crystal growth approach of the nitride system compound semiconductor of all layer systems.

[0033] Moreover, the gallium nitride system light emitting device of this invention is not necessarily effective in the laser structure shown in the example mentioned above, and is effective in the gallium nitride system laser of all structures. Furthermore, the gallium nitride system light emitting device of this invention is not necessarily effective in laser, and is effective also in light emitting diode. It is because it is advantageous that the cleavage plane of a substrate and an elevated-temperature growth epitaxial layer is in agreement also in light emitting diode in respect of the yield in the case of isolation etc. In addition, as shown in the example 2, it is not necessary to be C side strictly, and about surface side bearing of the silicon on sapphire in this invention, to C side, if it is less than 5-degree dip, it will be uninfluential in the effectiveness of this invention.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] In an example 1, it is the outline sectional view of the gallium nitride system laser which adopted In_{0.9}Ga_{0.1}N as a low dental-curing length buffer layer.

[Drawing 2] In an example 2, it is the outline sectional view of the gallium nitride system laser which adopted In_{0.9}Ga_{0.1}N (the 1st layer) and gallium nitride (the 2nd layer) as a low dental-curing length buffer layer.

[Drawing 3] In an example 2, it is the mimetic diagram showing the physical relationship of the atom of the silicon on sapphire and the In_{0.9}Ga_{0.1}N low dental-curing length buffer layer at the time of adopting C side silicon on sapphire as a substrate, and adopting In_{0.9}Ga_{0.1}N as a low dental-curing length buffer layer.

[Drawing 4] In the former, it is the mimetic diagram showing the physical relationship of the silicon on sapphire at the time of growing up the gallium nitride buffer layer which carried out low dental-curing length on C side silicon on sapphire, and the atom of a gallium nitride low dental-curing length buffer layer.

[Drawing 5] In the former, it is the outline sectional view of the gallium nitride system laser which adopted gallium nitride as a low dental-curing length buffer layer on C side silicon on sapphire.

[Drawing 6] In the former, it is the outline sectional view of the gallium nitride system laser which adopted gallium nitride as a low dental-curing length buffer layer on C side silicon on sapphire.

[Description of Notations]

101 C Side Silicon on Sapphire

102 In_{0.9}Ga_{0.1}N Low Dental-Curing Length Buffer Layer

103 N Mold In_{0.2}Ga_{0.8}N Contact Layer

104 N Mold In_{0.1}Ga_{0.9}N Layer

105 N Mold Aluminum_{0.15}Ga_{0.85}N Layer

106 N Mold Gallium Nitride Lightguide Layer

107 In_{0.2}Ga_{0.8}N/In_{0.05}Ga_{0.95}N Multiplex Quantum Well Barrier Layer

108 P Mold Aluminum_{0.2}Ga_{0.8}N Layer

109 P Mold Gallium Nitride Lightguide Layer

110 P Mold Aluminum_{0.15}Ga_{0.85}N Cladding Layer

111 P Mold In_{0.2}Ga_{0.8}N Contact Layer

112 P Electrode Which Consists of Nickel and Gold

113 N Electrode Which Consists of Titanium and Aluminum

202 Gallium Nitride Low Dental-Curing Length Buffer Layer

301 Silicon-on-Sapphire Oxygen Atom

302 Silicon-on-Sapphire A-axis Lattice Spacing

303 Silicon-on-Sapphire A-axis Lattice Spacing / Root3

304 Mth Page of Silicon on Sapphire

305 InGa_N Low Dental-Curing Length Buffer Layer Indium or Gallium Atom

306 InGa_N Low Dental-Curing Length Buffer Layer A-axis Lattice Spacing

307 Mth Page of InGa_N Low Dental-Curing Length Buffer Layer

405 Gallium Nitride Low Dental-Curing Length Buffer Layer Gallium Atom or Nitriding ALUMINIUM

MU low dental-curing length buffer layer aluminum atom

406 Gallium Nitride or Alumimium Nitride Low Dental-Curing Length Buffer Layer A-axis Lattice Spacing
407 Gallium Nitride or Mth Page of Alumimium Nitride Low Dental-Curing Length Buffer Layer
502 Gallium Nitride Low Dental-Curing Length Buffer Layer
601 Ath Page Silicon on Sapphire
602 Gallium Nitride Low Dental-Curing Length Buffer Layer
605 N Mold Aluminum0.12Ga0.88N Layer
607 In0.2 Ga0.8 N/In0.05Ga0.95N Multiplex Quantum Well Barrier Layer

[Translation done.]

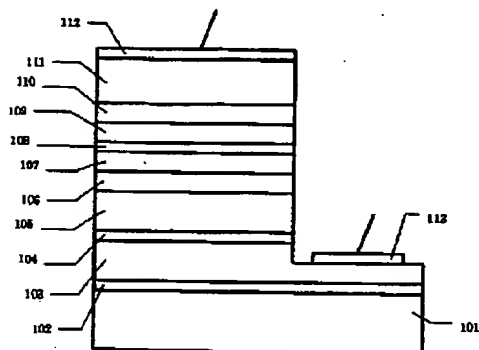
* NOTICES *

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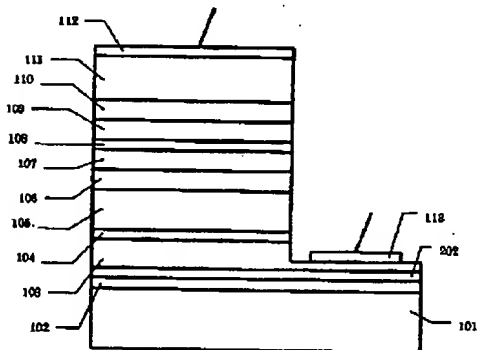
1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

DRAWINGS

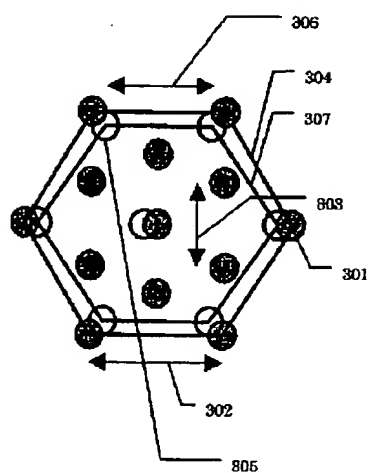
[Drawing 1]



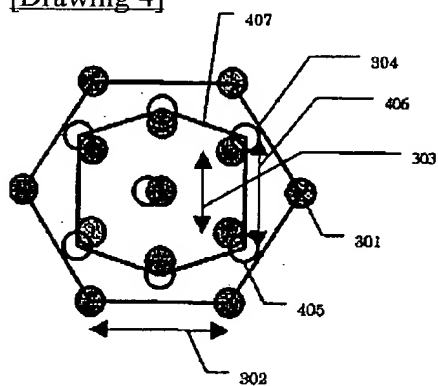
[Drawing 2]



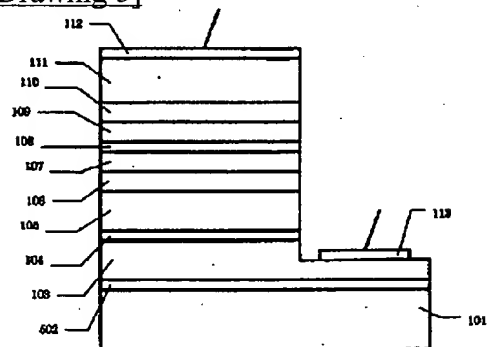
[Drawing 3]



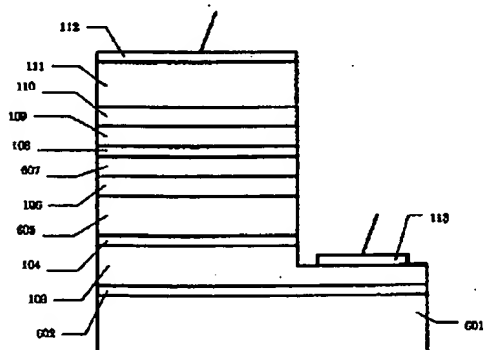
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]